

00/80/00

Express Mail Label: EL618698748US

11-09-00

Case No.: 1511-00

A

ASSISTANT COMMISSIONER FOR PATENTS
Washington, DC 20231

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): Keith Luker of Patterson, New Jersey

For: EXTRUDER MIXER

Also enclosed are:

 7 Sheets of drawings Recordation Form Cover Sheet - Patents Only and an Assignment of the invention to _____ Postcard and Express Mail Certification

The filing fee has been calculated as shown below:

	NO. OF CLAIMS FILED		NO. OF CLAIMS FROM BASIC FEE	NO. OF EXTRA CLAIMS
TOTAL	33	-	20 =	13
INDEP.	2	-	3 =	0

First presentation of multiple dependent claim

SMALL ENTITY

RATE	BASIC FEE \$355.
x 9 =	\$117.00
x40 =	\$
+135 =	\$

OTHER THAN SMALL ENTITY

OR

RATE	BASIC FEE \$710.
x18 =	\$
x80 =	\$
+270 =	\$

TOTAL FEE \$472.00 OR

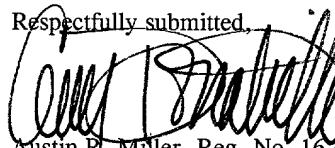
\$ _____

A check in the amount of \$ _____ is enclosed to cover the official filing fee for a large entity.

A check in the amount of \$472.00 is enclosed to cover the official filing fee for a small entity.

A check in the amount of \$ _____ is enclosed to cover the recordal fee.

Please charge my Deposit Account No. 13-3405 in the amount of \$ _____. A duplicate copy of this sheet is enclosed.

 In regard to this communication, the Commissioner is hereby authorized to charge payment of any additional filing fees required under 37 CFR §1.16 and any additional patent application processing fees under 37 CFR §1.17 or credit any overpayment to Deposit Account No. 13-3405. A duplicate copy of this sheet is enclosed. During the pendency of this application, the Commissioner is hereby authorized to charge payment of any filing fees for presentation of extra claims under 37 CFR §1.16 and any patent application processing fees under 37 CFR §1.17 or credit any overpayment to Deposit Account No. 13-3405. A duplicate copy of this sheet is enclosed.Respectfully submitted,
Austin R. Miller, Reg. No. 16,602
Guy T. Donatiello, Reg. No. 33,167
Schnader Harrison Segal & Lewis
1600 Market Street, 36th Floor
Philadelphia, PA 19103
Attorney for Applicant(s)ARM:rb
(215) 563-181010914 U.S. PTO
11/09/708225

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Art Unit :
Examiner :
Serial No. :
Filed : Herewith
Inventor : Keith Luker
Title : EXTRUDER MIXER

36th Floor
1600 Market Street
Philadelphia, PA 19103

Docket: 1511-00

Dated: November 8, 2000

JC914 U.S. PRO
09/708225
11/08/00

Box Patent Applications

Assistant Commissioner for Patents
Washington, DC 20231

EXPRESS MAIL CERTIFICATION

37 C.F.R. §1.10

Express Mail Label No.: EL618698748US

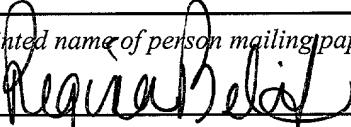
Date of Deposit: November 8, 2000

Description of Contents: Postcard, \$472.00 Check, Application Transmittal Letter, in duplicate, Specification including claims and abstract, and 7 sheet of drawings.

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR §1.10 on the date indicated above and is addressed to Box Patent Applications, Assistant Commissioner for Patents, Washington, DC 20231.

Regina Belitz

(*Typed or printed name of person mailing paper or fee*)


(*Signature of person mailing paper or fee*)

EXTRUDER MIXER

This invention relates to a new extruder mixer and method for mixing plastic or plastifiable materials, utilizing novel effects of elongational stress in the feed material, with improved mixing performance dramatically at all concentrations for the plastic mixture. The invention relates particularly to laboratory-scale mixers, and to their use in designing, building and operating full-scale production mixers using the novel concepts of this invention.

Laboratory extrusion machine builders have traditionally scaled down what the large extruder mixers have available in production. Nevertheless, when these large mixer designs are used in small extruders, they unfortunately do not compound very well.

Laboratory single screw compounders suffer from problems associated with being small. Lower shear rates, lower backflow, and the repercussions of using the same size pellets in laboratory extruders as in large extruders, all reduce the mixing compounder performance of small laboratory mixers.

Shear rates for a 5/8 inch extruder, for example, are roughly one-third that of a 4.5 inch extruder. Many workers regard higher shear rates as important to mixing. Small screws can generate much higher pressures than large extruders because of their small channel depths. Therefore, there is little back-mixing even at high pressure generation. It is a truism that, the better mixed the material enters the extruder, the better mixed is the output. Considering a simple mixture of conventional nominal 1/8 inch pellets mixed with a 1% additive concentrate of the same size and weight, one should consider how many standard 1/8 inch pellets are present at any given time in a 5/8 inch extruder compared with larger machines. For example, a 5/8 inch 24/1 L/D screw contains only 330 pellets or an average of 14 pellets per L/D. Yet a 2 inch screw contains about 905 pellets, a 3.5 about 3,600 pellets, and a 6 inch extruder about 384,000 pellets.

5

10

0920825
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
229
230
231
232
233
234
235
236
237
238
239
239
240
241
242
243
244
245
246
247
248
249
249
250
251
252
253
254
255
256
257
258
259
259
260
261
262
263
264
265
266
267
268
269
269
270
271
272
273
274
275
276
277
278
279
279
280
281
282
283
284
285
286
287
288
289
289
290
291
292
293
294
295
296
297
298
299
299
300
301
302
303
304
305
306
307
308
309
309
310
311
312
313
314
315
316
317
318
319
319
320
321
322
323
324
325
326
327
328
329
329
330
331
332
333
334
335
336
337
338
339
339
340
341
342
343
344
345
346
347
348
349
349
350
351
352
353
354
355
356
357
358
359
359
360
361
362
363
364
365
366
367
368
369
369
370
371
372
373
374
375
376
377
378
379
379
380
381
382
383
384
385
386
387
388
389
389
390
391
392
393
394
395
396
397
398
399
399
400
401
402
403
404
405
406
407
408
409
409
410
411
412
413
414
415
416
417
418
419
419
420
421
422
423
424
425
426
427
428
429
429
430
431
432
433
434
435
436
437
438
439
439
440
441
442
443
444
445
446
447
448
449
449
450
451
452
453
454
455
456
457
458
459
459
460
461
462
463
464
465
466
467
468
469
469
470
471
472
473
474
475
476
477
478
479
479
480
481
482
483
484
485
486
487
488
489
489
490
491
492
493
494
495
496
497
498
499
499
500
501
502
503
504
505
506
507
508
509
509
510
511
512
513
514
515
516
517
518
519
519
520
521
522
523
524
525
526
527
528
529
529
530
531
532
533
534
535
536
537
538
539
539
540
541
542
543
544
545
546
547
548
549
549
550
551
552
553
554
555
556
557
558
559
559
560
561
562
563
564
565
566
567
568
569
569
570
571
572
573
574
575
576
577
578
579
579
580
581
582
583
584
585
586
587
588
589
589
590
591
592
593
594
595
596
597
598
599
599
600
601
602
603
604
605
606
607
608
609
609
610
611
612
613
614
615
616
617
618
619
619
620
621
622
623
624
625
626
627
628
629
629
630
631
632
633
634
635
636
637
638
639
639
640
641
642
643
644
645
646
647
648
649
649
650
651
652
653
654
655
656
657
658
659
659
660
661
662
663
664
665
666
667
668
669
669
670
671
672
673
674
675
676
677
678
679
679
680
681
682
683
684
685
686
687
688
689
689
690
691
692
693
694
695
696
697
698
698
699
699
700
701
702
703
704
705
706
707
708
709
709
710
711
712
713
714
715
716
717
718
719
719
720
721
722
723
724
725
726
727
728
729
729
730
731
732
733
734
735
736
737
738
739
739
740
741
742
743
744
745
746
747
748
749
749
750
751
752
753
754
755
756
757
758
759
759
760
761
762
763
764
765
766
767
768
769
769
770
771
772
773
774
775
776
777
778
779
779
780
781
782
783
784
785
786
787
788
789
789
790
791
792
793
794
795
796
797
798
798
799
799
800
801
802
803
804
805
806
807
808
809
809
810
811
812
813
814
815
816
817
818
819
819
820
821
822
823
824
825
826
827
828
829
829
830
831
832
833
834
835
836
837
838
839
839
840
841
842
843
844
845
846
847
848
849
849
850
851
852
853
854
855
856
857
858
859
859
860
861
862
863
864
865
866
867
868
869
869
870
871
872
873
874
875
876
877
878
879
879
880
881
882
883
884
885
886
887
888
889
889
890
891
892
893
894
895
896
897
898
898
899
899
900
901
902
903
904
905
906
907
908
909
909
910
911
912
913
914
915
916
917
918
919
919
920
921
922
923
924
925
926
927
928
929
929
930
931
932
933
934
935
936
937
938
939
939
940
941
942
943
944
945
946
947
948
949
949
950
951
952
953
954
955
956
957
958
959
959
960
961
962
963
964
965
966
967
968
969
969
970
971
972
973
974
975
976
977
978
979
979
980
981
982
983
984
985
986
987
988
988
989
989
990
991
992
993
994
995
996
997
997
998
998
999
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1088
1089
1089
1090
1091
1092
1093
1094
1095
1096
1097
1097
1098
1098
1099
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1188
1189
1189
1190
1191
1192
1193
1194
1195
1196
1197
1197
1198
1198
1199
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1288
1289
1289
1290
1291
1292
1293
1294
1295
1296
1297
1297
1298
1298
1299
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1388
1389
1389
1390
1391
1392
1393
1394
1395
1396
1397
1397
1398
1398
1399
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1488
1489
1489
1490
1491
1492
1493
1494
1495
1496
1497
1497
1498
1498
1499
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1588
1589
1589
1590
1591
1592
1593
1594
1595
1596
1597
1597
1598
1598
1599
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1688
1689
1689
1690
1691
1692
1693
1694
1695
1696
1697
1697
1698
1698
1699
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1788
1789
1789
1790
1791
1792
1793
1794
1795
1796
1797
1797
1798<br

If we imagine a perfectly mixed 1% additive of the same pellet size, the 5/8 inch extruder will contain only 3 pellets of the additive, spread throughout 24 L/Ds of extruder length! The extruder is required to mix one pellet into 8 L/Ds of length. Even a small 2 inch extruder processes a remarkable improvement in the quality of the incoming mixture as it will have 9 additive pellets in each L/D of extruder length. Larger machines obviously have more.

The problem is worse than this, in practice, because the mixture is unlikely to be perfectly mixed. In the foregoing "3 pellet per 8 L/D" example, it is very probable that only 2 or as many as 4 pellets could be in the extruder at one time. Accordingly, there will be times when only 1 pellet might be present. If the hopper mixture were slightly uneven, there might even be a time with no additive pellets in the entire screw -- a difficult mixing problem to be sure.

This problem is so unlikely to exist in large extruders that it needs no consideration. The possible use of micro-pellets would seem to avoid these problems but such pellets are expensive, inconvenient, and often require at least one additional processing history. Accordingly, it would be highly advantageous to resolve the problem even with the use of standard or typical pelletized feed stocks.

Most single screw extruders are flood fed, by filling the hopper and the screw channel to its limit. However, compression of solids is not necessarily consistent with good mixing. In a compressive extruder where equal amounts of two types of pellets, A and B, are to be mixed in the extruder, on entering the screw, it is extremely unlikely that the mix will be perfect, i.e. A-B-A-B-A-B-A-B etc. Some inconsistent sequence will likely occur such as A-A-A-A-B-B-B-B. Compression of this sequence at high pressure often results in very sturdy "A" and "B" material where each agglomeration has to be broken up, i.e., mixed by dispersion, and then mixed intimately with each other, i.e., by distribution. This is inherently

counterproductive to good mixing.

The creation of the vertically oriented extruder improved the laboratory extruder itself, with its natural advantages of better feeding and screw strength, and dramatic increase of the L/D ratio. This is possible because the vertical screw is in tension rather than compression. This eliminates the buckling forces (caused by pressure at the tips of other screws) that otherwise destroy long small screws.

Length is an important attribute of a screw for many reasons. Length presents the opportunity to begin the melting process without compression.

BACKGROUND OF THE INVENTION

Of the many mixing elements that have been made, three fluted mixers are of particular interest. These are the mixers of G. LeRoy U.S. Patent No. 3,486,192, R.B. Gregory and L.F. Street U.S. Patent No. 3,411,179, and R.G. Dray, U.S. Patent No. 3,788,612. These mixers are often claimed to have dispersive mixing properties because the barrier clearance within the inner wall of the outer cylinder of the extruder is so small that the material is subjected to a high shear rate, the corresponding shear stress then being large enough to break down particles in the polymer melt. An important assumption in this prior art analysis is that the mixer is filled with plasticized material under compression. For example, in R.G. Dray U.S. Patent No. 3,788,612, since the material is described as plasticized and forced through increasing resistance through the mixing element, the intention of the patent is to force material, under compression, through this mixing element. The foregoing will be seen to be contrary to the substance of this invention.

SUMMARY OF THE INVENTION

In this invention the mixer is preferably an integral part of the melting zone of the screw. Therefore, the mix viscosity at the mixer is much higher than otherwise. This allows the creation of a tensile stress on the mixture, and enables novel elongational dispersion of

the mixture in the melting zone.

In order to mix at the optimum level, only a minimum amount of pressure is applied to deliver the feed material to the inlet channel of the mixer. Once the incoming plastic material enters the inlet channel, it meets one or a succession of cross-axial pumping members preferably having substantial clearance with the outer shell of the extruder, and each one takes on a cross-axial pumping function. When the cross-axial pumping, effective at an angle to the extruder axis, exceeds the inlet flow, the pumping function causes the inlet channel to become partially emptied. The plastic material that approaches each cross-axial pump is then stressed in elongation rather than compression, and remarkable mixing dispersion takes place. As the material then moves over each cross-axial pump, it is reoriented in a planar shear field. These successive reorientations take place in the absence of a worm flight as typically exists to generate pressure between two successive mixing elements. This effect may be further augmented by starve feeding of the plastic feed into the extruder, which may be controlled or assisted by screw design. Starve feeding adds a great deal of flexibility to the process and to optimization of the mixing process.

To encourage or reduce the amount of remixing, for example, additional feed rate to fill the end of the inlet channel with plastic material can be used as a control.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will further be described in detail in the drawings, which are intended to be illustrative but are not intended to define or limit the scope of the invention, which is defined in the appended claims.

Figs. 1(a) and 1(b) are views in showing a mixer in accordance with this invention.

Figs. 2(a) and 2(b) are views in side elevation showing a mixer in accordance with this invention.

Figs. 3(a) and 3(b) are side and sectional views showing a modified form of the

invention.

Figs. 4(a) and 4(b) are fragmentary side sectional views, representing a preferred embodiment of this invention, as will further be described hereinafter.

Figs. 5(a) and 5(b) represent a further embodiment in accordance with this invention.

Fig. 6 comprises Fig. 6(a) and 6(b) in accordance with this invention, showing a multiplicity of inlet channels, outlet channels and cross-axial pumps as will further be described in detail hereinafter. Fig. 6(a) is a sectional view taken through the mixer of Fig. 6(b), along the lines and arrows V-V; and

Figs. 7(a) and 7(b) show a further embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The current invention optimizes the mixing that takes place in a limited axial space along the extruder screw by providing multiple passes of plastic material drawn through a plurality of elongational mixing zones. This gives much greater latitude in design and achieves much better mixing results than heretofore suggested, as will further appear hereinafter.

In a mixer of this invention, the plastic material flow is shown schematically in Figs. 1(a) and 1(b) of the drawings. First inlet channel 21 is starved (partially empty) conveying material to first cross-axial pump 22. As the flow accelerates into cross-axial pump 22, an important improvement in mixing is created. Cross-axial pump 22 reorients the material in planar shear while pumping into the second channel inlet 23. Second channel inlet, also starved, conveys material to the inlet to subsequent cross-axial pump 24. Cross-axial pump 24 then functions as an output channel.

Fig. 2(b) shows the four flights 26 that tend to induce a certain amount of downstream flow in the various adjacent inlet channels.

First inlet channel 21 is starved (partially empty) conveying material to first cross-

axial pump 22. As the flow accelerates into cross-axial pump 22, an important improvement in mixing is created. Cross-axial pump 22 reorients the material in planar shear while pumping into second channel inlet 23. Second channel inlet 23, also starved, conveys material to the inlet to subsequent cross-axial pump 24 where subsequent acceleration and further mixing improvements take place. Subsequent cross-axial pump 24 further reorients the material in planar shear while pumping material to subsequent inlet channel 25. After subsequent mixing and pumping, material is delivered to final output channel 27. The cross-axial pumps 22 and 24 pump the mixture at an angle such as (a) in Fig. 2(a) and draw off the material from the inlet channels 21, 23, 25 until the supply is exhausted.

In the preferred embodiment shown in Fig. 4, the screw (which is driven in rotation by any suitable power source, not shown) has fifteen sections of inlet channels 11, cross-axially acting pumps and one outlet channel 12, and therefore provides exceptional mixing. Further flight 26 is shown to become a connected inlet and outlet flight that both guides material to first inlet channel 11 and from outlet channel 12.

Previous mixers have attempted to force material from one channel, over a barrier, and into a flight or channel such as in LeRoy U.S. Patent No. 3,486,192 and Dray U.S. Patent No. 3,788,612. Dray forced material from channel to flight in an uncontrolled manner, as shown in Dray U.S. Patent No. 3,788,612. By forcing, the flow fields were compressive rather than extensional.

The invention of Figs. 2 and 4 achieves a series of mixing stages, in extensional plastic material flow fields, in a short axial length compared to the length of the extruder screw. Extension of the plastic material is achieved by cross-axial drawing of the mixture from one channel directly to another channel at reduced pressure and preferably by operation in which the channels are in a partially empty mode. This latter mode may be achieved by starve feeding the inlet to the mixer, preferably by limiting the input amount by combined

use of a starve feeder (such a variable speed volumetric feeder) or, for example, by limiting the amount of material received by the mixer as a matter of screw design prior to the mixer.

It has heretofore been suggested, contrary to this invention, to provide possible means to reduce the amount of remixing. There is no mechanism suggested, to the best of my knowledge, that causes substantially all of the material to be remixed, as in this invention. Indeed, it has been indicated that additional feed rate to fill the end of the inlet channel would prevent remixing.

Fig. 5 of the drawings, like Figs. 2(a) and 2(b), shows disconnected inlet and outlet flights 8, 9 and also shows a multiplicity of inlet channels 1, 3, 5 and a multiplicity of outlet channels 7, with intervening cross-axial pumps 2, 4, 6 pumping in angular directions such as (a), (b), which are important features in accordance with this invention.

Figs. 6(a) and 6(b) show another embodiment of this invention comprising a multiplicity of these inlet and cross-axial pumping channels, working in combination with connected output flight 26 and where first cross-axial pump 22, second inlet channel 23, subsequent cross-axial pumps 24 and subsequent inlet channels 25 are bounded by a flight on two sides. This embodiment substantially prevents downstream flow from entering the mixer. The first inlet channel bears the number 21, the first cross-axial pump 22, the second inlet channel 23, the subsequent cross-axial pump 24, the subsequent inlet channel 25. The arrows (a) and (b) indicate cross-axial pumping, and arrow (c) designates downstream flow. The flight in the mixer section is identified as 26, while the final output channel is identified by the number 27. The input and output portions of flight 26 are identified as 28 and 29.

Figs. 3(a) and 3(b) show the use of a reverse screw flight 30 in a mixer otherwise similar to Figs. 2(a) and 2(b). In Figs. 3(a) and 3(b) the plastic material flow is from right to left, with the reverse flight urging the plastic material toward the right, into the outlet channels of the mixer for the purpose of control. It is preferred to limit the reverse effect to

avoid completely filling the mixer, because the mixer would then become compressive and lose the benefits of this invention.

Referring to Figs. 7(a) and 7(b), this embodiment includes a blister ring 31 to urge the plastic material toward the right, countercurrently. The blister ring 31 is a non-axial pumping ring which is designed as a narrow ring to control the mixer to be not quite filled, because it would then become compressive.

As an alternative, the channel depth could be reduced downstream of the mixer to decrease its pumping capacity, causing some plastic material to back up into the empty mixing channels.

It has been suggested that notches in the flight will permit material to flow through the flight into the inlet channel. Thus, the concept of notches permits material to flow either into one of the inlet channels or continued to be pumped out a discharge channel. This has serious drawbacks that the present invention overcomes.

A flight such as 26 in Fig. 6(b) has a small radial clearance from the extruder housing. A channel according to this invention has a large radial clearance from the extruder housing.

The flight 26 restricts flow for the purpose of promoting flow down and along the outlet channel. It is preferred for the flight 26 not to be a notched flight. A notched flight primarily promotes material into an inlet channel through the notches. When such flow exceeds the pumping capacity of the cross-axial pumps 22, 24, for example, the mixer flow will become undesirably compressive. A flight such as 26 in this invention includes variations in design sufficient to maintain elongational, non-compressive, flow in the mixer.

Although this invention has been described with reference to specific embodiments thereof, it will be appreciated that many variations may be made in the specific design of the extruder and its mixing section, including variations of the numbers and arrangements of inlet channels, cross-axial pumps, the number of inlet channels and cross-axial pumps, and

5

10

the number and arrangement of subsequent outlet channels. It will further be appreciated that the flight at the input and the exit ends of the mixing section can either be connected to or disconnected from the channels. Further, although it has been indicated as preferred to utilize a separate starve feeding mechanism, the invention is fully capable of operating with benefit and advantage in the absence of any such controlling mechanism. The dimensions of various channels may be specially designed to be similar or different from each other, where plural channels are utilized, and the dimensions of the first and subsequent cross-axial pumps can differ from each other. Although the channels may be oriented parallel to the screw axis, they may be angled as well. Further, some of the channels may be non-inlet channels and bounded by a flight on one side or more than one side. Many other variations may be made, as will readily become apparent to those skilled in the art.

SEARCHED INDEXED
SERIALIZED FILED

What Is Claimed Is:

1. An extruder mixer for plastified material comprising a rotatable elongated screw and means for rotating said screw, said screw having a mixing section adapted to mix plastified materials, said mixing section having an inlet channel connected to a cross-axial pump constructed and arranged to feed a subsequent said channel, wherein said subsequent channel is connected to further feed said mixture to at least one subsequent cross-axial pump that is bounded by a flight on at least one side of said output channel to deliver the resulting plastic mixture.

2. The apparatus of Claim 1, wherein the cross-axial pumps are bounded by channels on more than one side.

3. The apparatus of Claim 1, wherein an upstream feeder is connected to cause and to control input feed of mixable materials.

4. The apparatus of Claim 1, where a screw channel is provided at the input of said mixer to control the flow rate mixer input.

5. The apparatus of Claim 1, where an output flight is connected to a downstream flight of said mixer section.

6. The apparatus of Claim 1, where an output flight is connected to a channel of said extruder mixing section.

7. The apparatus of Claim 1, wherein the dimensions of said first and subsequent

channels are substantially the same as each other.

8. The apparatus of Claim 1, wherein said extruder screw is substantially vertically oriented.

9. The apparatus of Claim 1, wherein the dimensions of said first and subsequent channels are different from each other.

10. The apparatus of Claim 1, wherein the dimensions of said first and subsequent cross-axial pumps are the same.

11. The apparatus of Claim 1, wherein the dimensions of said first and subsequent cross-axial pumps are different from each other.

12. The apparatus of Claim 1, wherein said channels are oriented substantially parallel to the screw axis.

13. The apparatus of Claim 1, wherein said channels are oriented at an angle to the screw axis.

14. The apparatus of Claim 1, wherein at least some of the channels are unconnected to said inlet channel and are bounded by a flight on one side.

15. The apparatus of Claim 14, wherein at least some of said non-inlet channels are bounded by a flight on two sides.

16. The apparatus of Claim 1, wherein said mixer is not starve fed.

17. The apparatus of Claim 1, where resistance devices are provided on said screw to force said plastic material into said outlet channels.

18. The apparatus of Claim 1, wherein there are multiple inlet channels.

19. The apparatus of Claim 1, wherein there are multiple connected inlet flights.

20. The apparatus of Claim 1, wherein there are multiple connected outlet flights.

21. In a method of mixing plastic or plastifiable materials in an extruder comprising a rotatable extruder screw having a mixing section comprising a plurality of inlet and outlet channels for said materials, the steps which comprise:

(a) drawing said materials into an inlet channel,

(b) cross-axially pumping said material from said inlet channel to at least one subsequent said inlet channel, and

(c) cross-axially pumping said material.

22. The method of Claim 21, comprising the further step of cross-axially pumping said material into an outlet channel.

23. The method of Claim 21 comprising the further step of controlling upstream feed of input of said material to said extruder.

24. The method of Claim 23, wherein said input is fed through a screw channel, and wherein said step of controlling comprises constraining the feed rate of said screw channel.

25. The method of Claim 21 comprising the further step of controlling the rate of material output from said outlet channel.

26. The method of Claim 23, wherein an output flight is connected to a channel of said extruder, and wherein said step of controlling comprises limiting the rate of rotation of said output flight.

27. The method of Claim 21, comprising the step of starve feeding said extruder.

28. The method of Claim 21 comprising the step of applying resistance to output material flow to force said plastic material into said outlet channel.

29. The method of Claim 21 comprising the step of introducing said plastifiable material separately into a plurality of separate inlet channels.

30. The method of Claim 21 comprising the step of concurrently feeding said plastifiable material into a multiplicity of individual channels.

31. The method of Claim 21 including the further step of connecting a plurality of said channels together for concurrent flow of said material therein.

32. The method of Claim 21 comprising the step of removing said mixed material

concurrently through a plurality of multiple outlet flights.

33. The method of Claim 21 comprising the further step of maintaining said plastifiable material in a melted state within said mixing section.

ABSTRACT OF THE DISCLOSURE

An extruder mixer and method for mixing plastic materials utilizes an elongated screw having an inlet channel connected to a first cross-axial pump that feeds, at an angle to the screw axis, a subsequent channel, wherein the subsequent channel becomes a further inlet channel connected to at least one subsequent cross-axial pump, and wherein the cross-
5 axial pump is bounded by a flight on at least one side.

DRAFTING DRAWING ATTACHED

FIG. 1 (a)

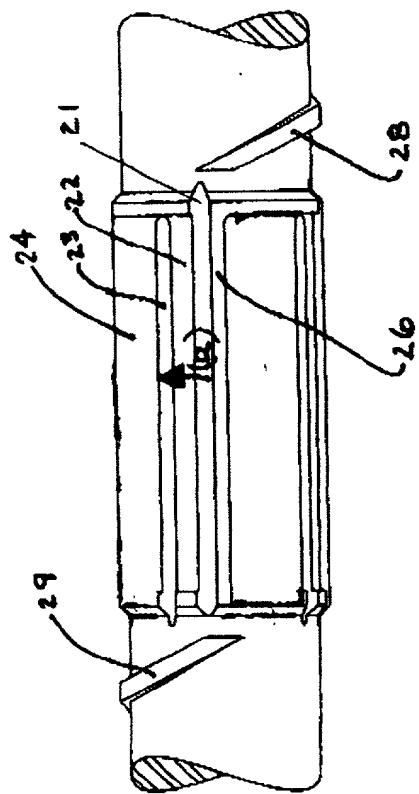


FIG. 1 (b)

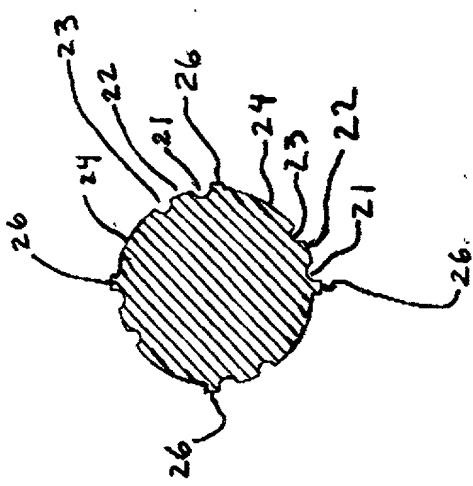


FIG. 2(a)

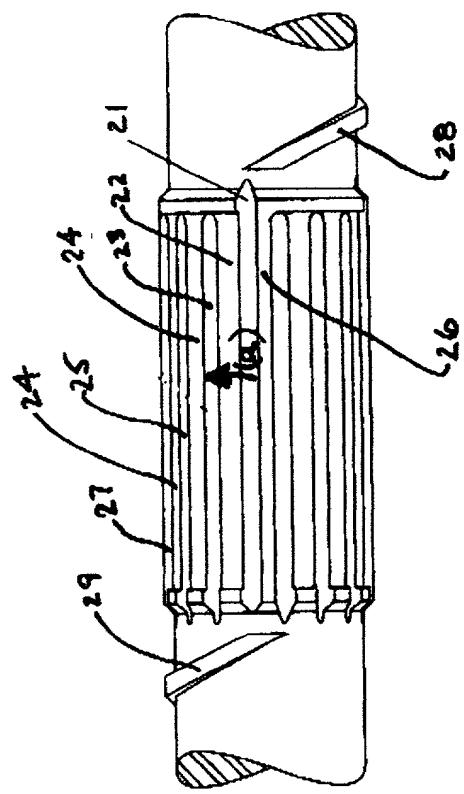
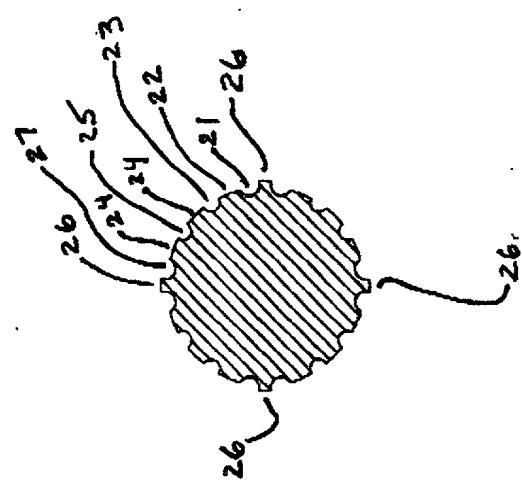


FIG. 2(b)



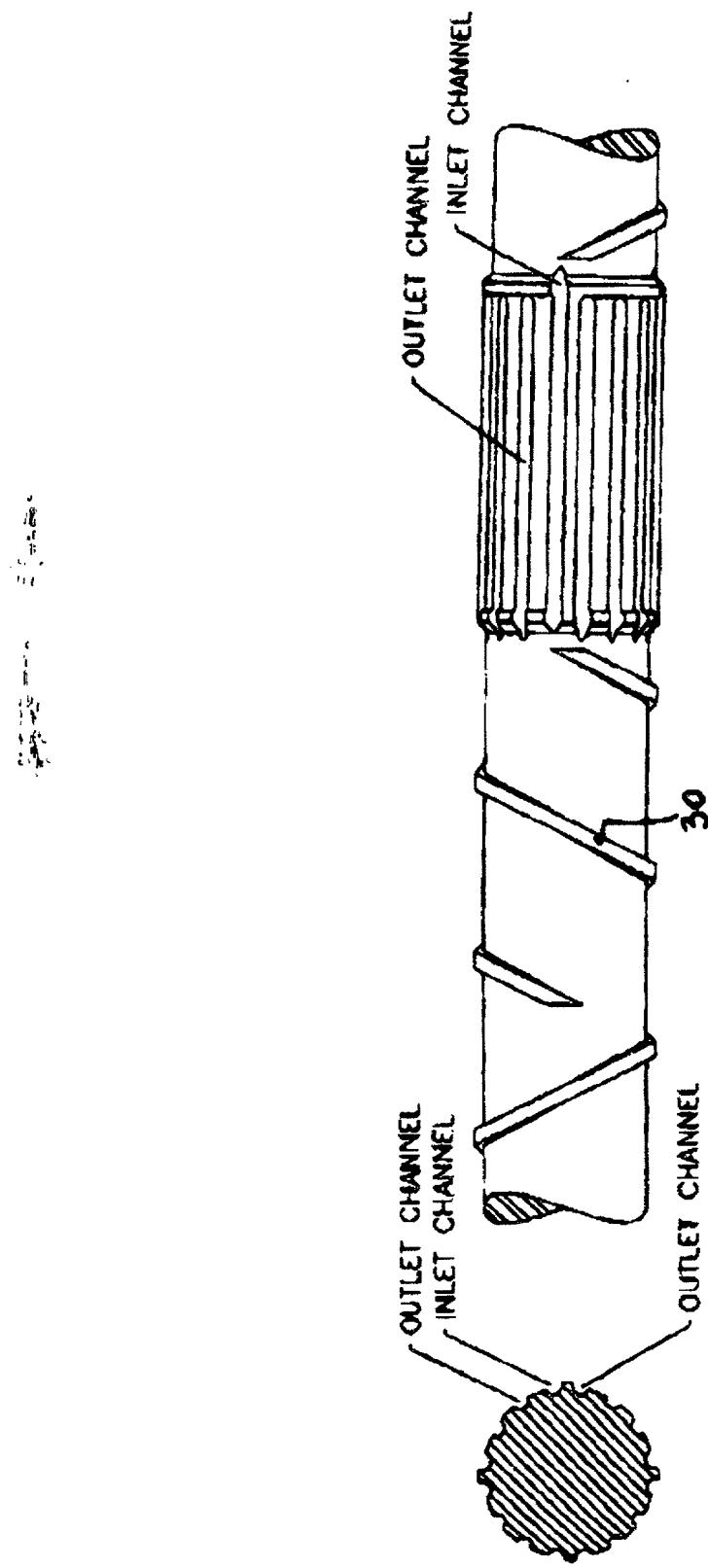


FIG. 3(a)

FIG. 3(b)

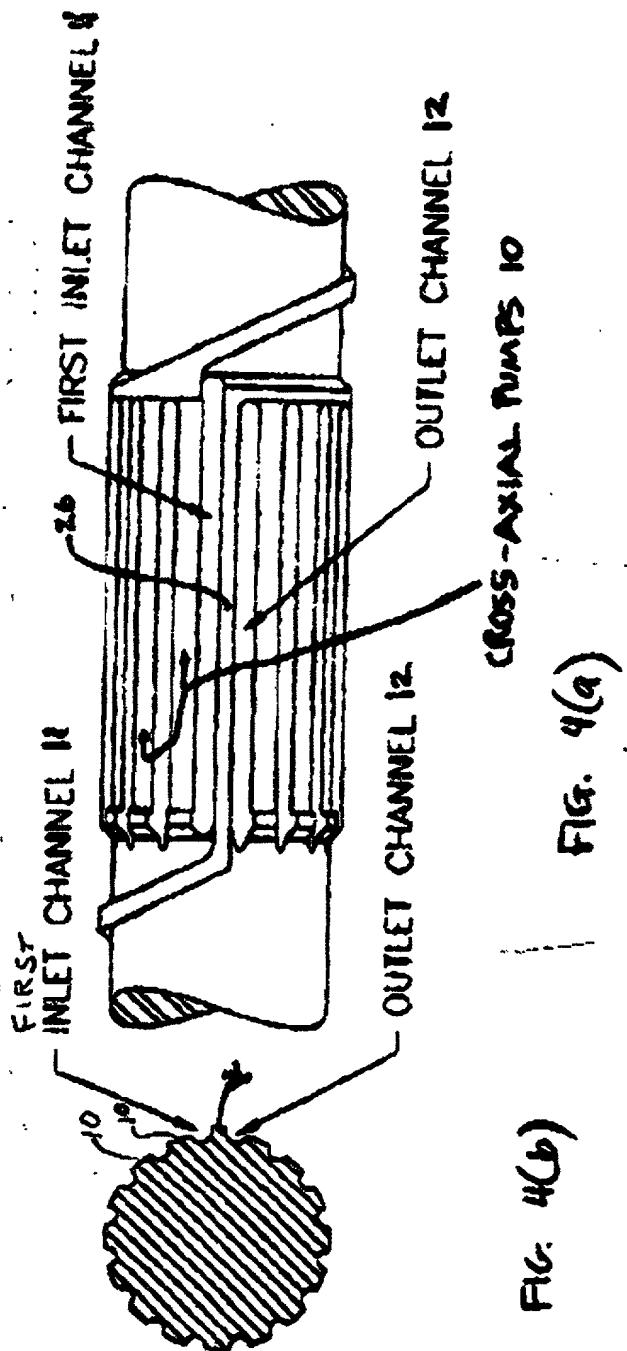
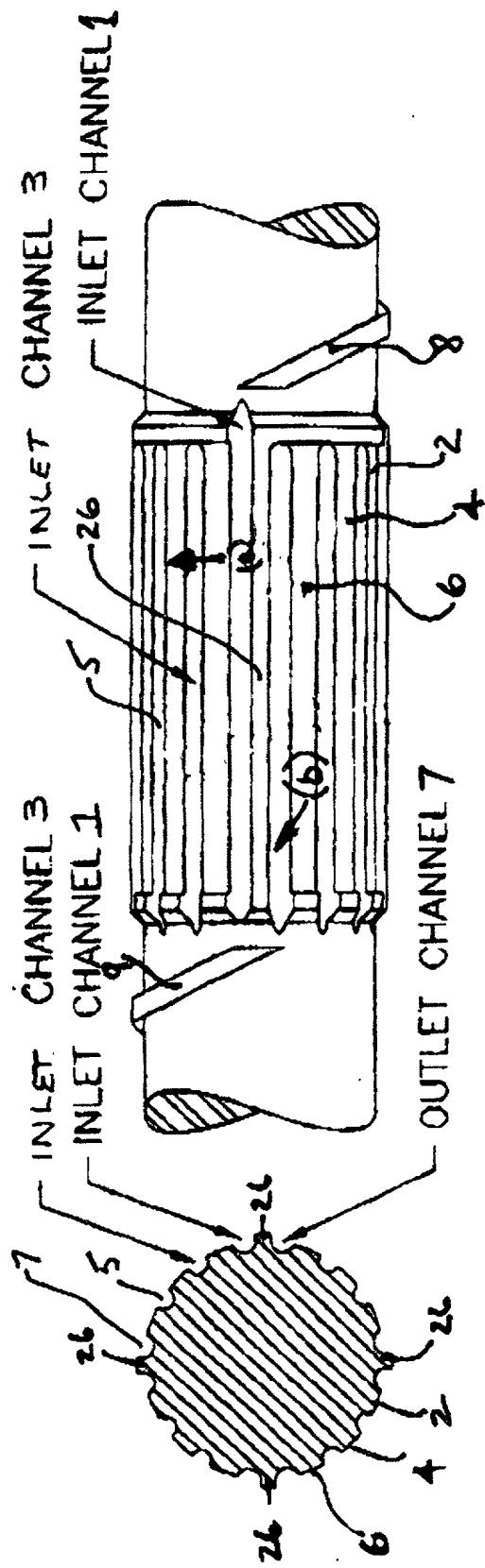


FIG. 4(b)

FIG. 4(a)



CROSS-AXIAL PUMPS

FIG. 5(b)

FIG. 5(a)

FIG. 6(b)

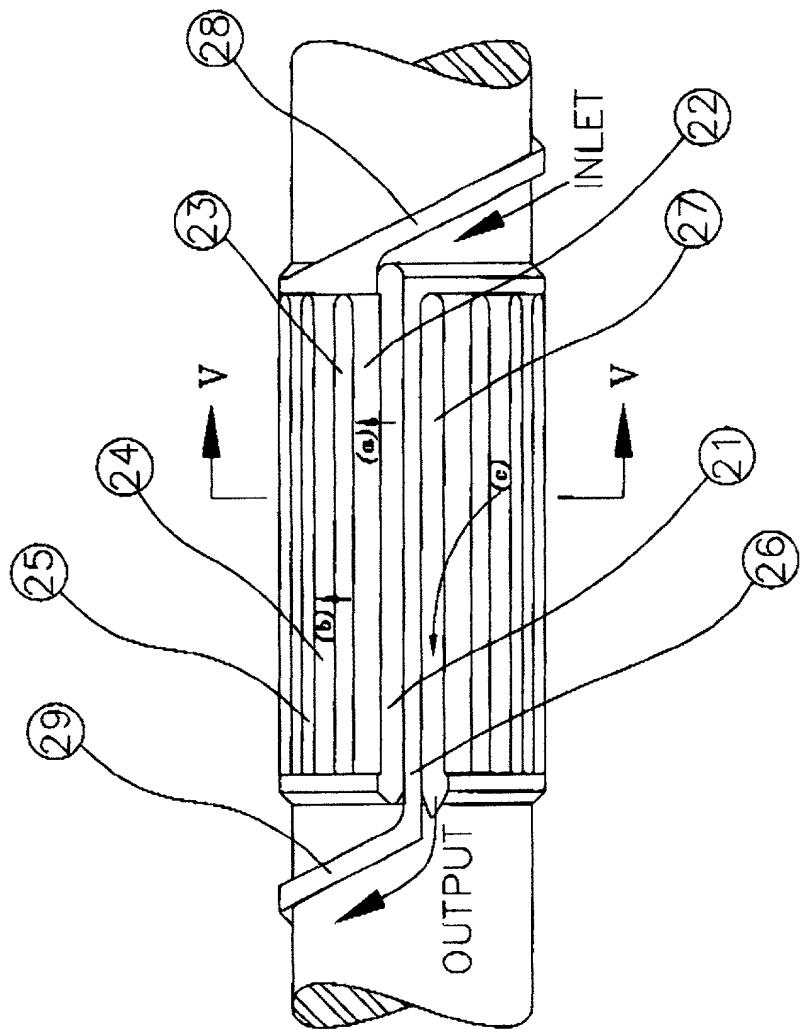
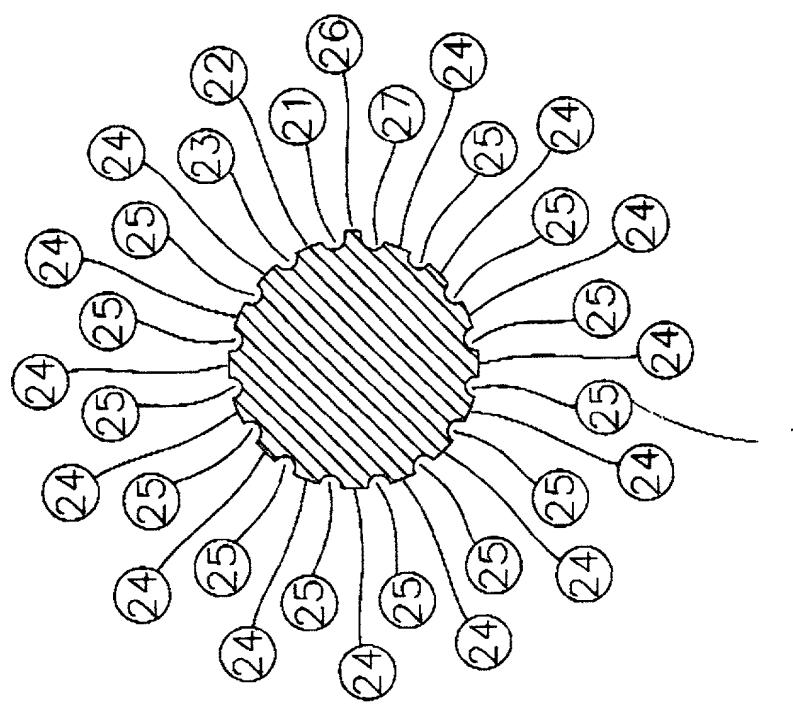


FIG. 6(a)



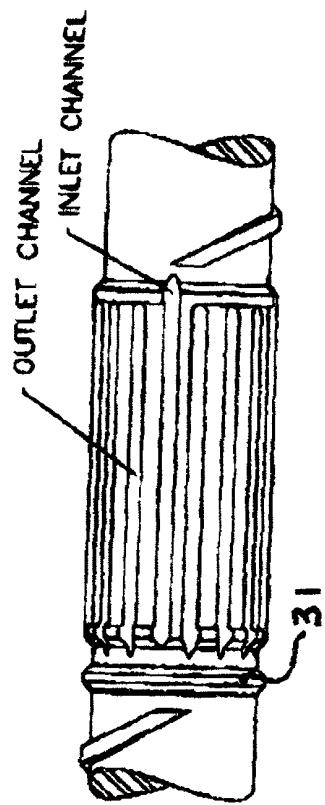


Fig. 7(a)

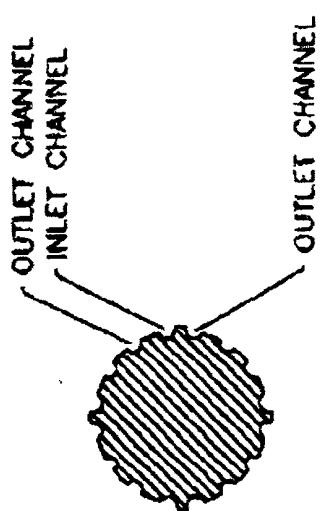


Fig. 7(b)